TITLE OF THE INVENTION

ON-LINE IMAGE PROCESSING AND COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

[0001] The present invention generally relates to miniPACS (Picture Archiving and Communications System) or teleradiology systems, specifically to miniPACS/teleradiology systems with remote volume data processing, visualization, and multi-user conferencing capability. In our previous patent application, United States Patent Application Serial No. 09/434,088, we presented a miniPACS/teleradiology system with remote volume data rendering and visualization capability. The present invention is directed to additional features and enhancements of the architecture described therein.

[0002] Teleradiology is a means for electronically transmitting radiographic patient images and consultative text from one location to another. Teleradiology systems have been widely used by healthcare providers to expand the geographic and/or time coverage of their service and to efficiently utilize the time of healthcare professionals with specialty and subspecialty training and skills (*e.g.*, radiologists). The result is improved healthcare service quality, decreased delivery time, and reduced costs.

[0003] One drawback to some existing teleradiology systems, however, is the lack of the ability for radiologists to communicate interactively with their colleagues and referring physicians from disparate locations for the purpose of consultation, education, and collaborative studies. Collaboration is especially important for studies using volumetric images, where the ability to interactively manipulate the volumetric images and simultaneously view the processed images is essential for rapid and effective communications between multiple participants involved.

[0004] There are numerous methods and systems providing multi-media network based conferencing capability. However, these methods and systems

only support shared viewing of texts, documents, and videos. Furthermore, a radiology conferencing system presents unique obstacles. For example, the size of data to be transmitted could be very large and the requirement on image (picture) quality could be very high. To be clinically useful, the transmission should be interactively "on-demand" in nature. There are on-going efforts to develop radiology conferencing capabilities for the communication of two-dimensional (2D) images. However, none of these systems supports interactive communication of volumetric/three-dimensional (3D) images.

[0005] As a result, there exists a need for a miniPACS/teleradiology system with network based conferencing capability supporting synchronized distribution and viewing of interactively processed volumetric images. Further, there exists a need for an improved method and procedure for the management of multi-center trials involving volumetric images.

SUMMARY OF THE INVENTION

[0006] The present invention provides a computer architecture for a client/server-based advanced image processing and rendering system. The present invention further provides a computer architecture to support multi-user concurrent usage of the processing server. The present invention includes a method and apparatus that combines the network-based conferencing capability with remote interactive advanced image processing capability. The present invention enables users from disparate locations to interactively manipulate images and simultaneously view the processed images in an independent or synchronized fashion. The present invention further enables a user to interactively view and manipulate the images without having to download the entire volumetric data set. The present invention also includes improved methods and procedures for radiology consultation and multi-center trial management involving volumetric images using the above-mentioned technology.

[0007] The present invention may be used for radiology consultation. In one step, the acquisition of 2D or 3D/volumetric image/data sets or retrieval of previously acquired image/data sets is performed. The volumetric data set could be three-dimensional in space, or two- or three-dimensional in space and one-dimensional in time, *e.g.*, time-resolved spatial data sets. In another step, data is moved to a server, which could be the scanner workstation itself or a separate computer connected to a network, and which has the conferencing software. In another step, client software is initiated by a remote user/users. Each user is able to remotely access and manipulate the 2D as well as volumetric/3D images with full processing capabilities, including Multiplanar Reformat (MPR), Maximum Intensity Projection (MIP), Volume Rendering, Image segmentation, and etc. As described in the preferred embodiment, an user may send the image processing request, such as MPR request to the server, the server will render the images accordingly and send the result back. In another step, each user is able to interactively manipulate volumetric images without transferring the entire dataset, employing an "on-demand" image transmission method.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Fig. 1 depicts a block diagram of the present invention.

[0009] Fig. 2 depicts an alternative diagram of the present invention.

[0010] Fig. 3 depicts a flowchart of method of the present invention.

[0011] Fig. 4 depicts a description of state parameters which may be used in one embodiment.

[0012] Fig. 5 depicts a flowchart of the state parameter updating method.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0013] Fig. 1 depicts the teleradiology system described in our previous patent application, United States Patent Application Serial No. 09/434,088. The teleradiology system includes as data transmitting station 100, a receiving

station 300, and a network 200 connecting the transmitting station 100 and receiving station 300. The system may also include a data security system 34 which extends into the transmitting station 100, receiving station 300, and network 200. Receiving station 300 comprises a data receiver 26, a send request 22, a user interface 32, a data decompressor 28, a display system 30, a central processing system 24, and, data security 34. Transmitting station 100 comprises a data transmitter 16, a receive request 20, a data compressor 14, a volume data rendering generator 12, a central processing system 18, and, data security 34.

[0014] Many image visualization and processing tasks (such as volume rendering) consist of multiple interactive sub-tasks. For example, visualizing a dataset consists of at least two steps (subtasks): 1) generating a processed image to be displayed; 2) displaying the image. In a client/server-based image processing system, some subtasks are performed by the client and the other by the server. Using the above example, generating the processed image to be displayed can be performed in entirety on the server, or, partially on the server and partially on the client. Displaying the processed image is performed on the client.

[0015] Referring now to Fig. 2, a system is shown wherein, as contemplated in the present invention, several receiving stations 300a-e have access over a network 200 to a transmitting station. Each of the receiving stations 300a-e are structured similarly to the receiving station 300 shown in Fig. 1. The transmitting station may be considered the server and the receiving stations the clients to use the client/server terminology.

[0016] Referring now to Fig. 3, a flow chart representing steps performed according to one preferred embodiment is shown. At step 401, one or more users initiate a session by logging in to the server from one of the receiving stations 300a-e. At step 402, one of the logged in users issues a command to form a conference, and identifies a list of users who may participate in the conference. The user who initiates the conference, *e.g.*, the user at receiving station 300a shown in Fig. 2, may be designated as the conference "driver" by

default. The conference driver may be, for example, a consulting radiologist. Other designated conference participants may join the conference. Alternatively, the driver may review the list of users logged in and select persons to participate in the conference. The other participants may be, for example, 3D technologists, other radiologists, referring physicians, or other healthcare personnel. The driver has the ability to accept or reject a request to join. Alternatively, the driver may designate that the conference is "open," *i.e.*, that other users may join in without an express authorization being made by the driver.

[0017] At step 403, the driver initiates a processing command from the client side. In a preferred operation, the driver, using interface 32, specifies: 1) at least one image data set to be visualized; 2) at least one data rendering method to be used; 3) the rendering parameters used by each rendering method, 4) data compression parameters, and 5) the data transmission parameters for controlling data transmission over network 200. Examples of state parameters are provided in Fig. 4. In particular, the driver may, via user interface 32, adjust rendering parameters, *e.g.*, viewpoint, spatial region, and value range of the data to be rendered, and other settings. The techniques for setting and adjusting these parameters include 1) using preset protocols for some typical settings; 2) inputting a specific setting with a keyboard, a mouse and/or other input devices; and/or 3) interactive navigation using a mouse, a trackball, a joystick, a keyboard and/or other navigating devices. This driver may, via user interface 32, edit (including process) patient data, *e.g.*, remove the bone structures, in a manner similar to the current volume data rendering/visualization systems. With the teleradiology system of the invention, driver can, via user interface 32, define and adjust data rendering methods and parameters, control what is to be rendered, transmitted and visualized next, and eventually obtain the final rendering result. A central processing system 24 on the driver's receiving station receives and validates the driver's request. The central processing system 24 then issues the request,

which is sent via send request 22 to transmitting station 100 through network 200.

[0018] At step 404, the central processing system 18 on the transmitting station 100 receives the request via receive request 20. Coordinated by central processing system 18, volume data rendering generator 12 accesses from image data source 10 the image data set which the user has specified, and then generates the data rendering result based on the data rendering method and parameters which the user has specified. The rendering result may be a 2D image, much smaller in size than the original data set.

[0019] At step 405, the data transmitter 16 on transmitting station 100 transmits the compressed data to data receiver 26 on receiving stations 300a-e which have sent a request for image data, *i.e.*, on-demand, via network 200 based on data transmission parameters which the user has specified. The on-demand feature of the present invention will be describe further in connection with Fig. 5. For the teleradiology system of the invention, the preferred transmission medium (*i.e.*, network 200) may be an intranet, the Internet (including the Internet2) or a direct dial-up using a telephone line with a modem. The preferred data transmission protocol is the standard TCP/IP, although the method may be adapted to accommodate other protocols. Furthermore, for some transmission media (*e.g.*, the Internet2), user 400 can control certain aspects (e.g., the priority level, the speed) of data transmission by selecting transmission parameters via user interface 32.

[0020] At step 406, the central processing systems 24 of the various receiving stations 300a-e coordinate the client-side processing. If needed, data decompressor 28 decompresses (or restores) the rendering result. The central processing system 24 may also perform further image processing and operations. The processing is performed in which the final image is computed based on the field of view and the image window/level (i.e., brightness/contrast) settings currently prescribed by the conference driver.

[0021] At step 407, the display systems 30 at receiving stations 300a-e display the computed image and other parameters. Via user interface 32, the driver

may further modify parameters, including 1) the image data set to be visualized, 2) the data rendering method to be used, 3) the rendering parameters used, and 4) the data transmission parameters used. This process goes on until a satisfactory rendering and visualization result is obtained.

[0022] The set of image processing and display parameters, collectively called state parameters, keep track of the effect of image processing, performed either at the server or at a client, and if needed, synchronize the display (viewing) of multiple users. Examples of state parameters are given in Fig. 4. Each time when a new subtask is performed, this set of the state parameters is updated at the server. Any further image processing and display task will be performed based on this set of updated state parameters.

[0023] In one embodiment, the resulting images are "pulled" to the clients from the server. When a client with the driver authorization prescribes an operation and regardless of whether this operation is performed on the client, the server, or the both, the state parameters will be updated on both the server and the driving client to reflect the resultant change due to this operation. Other clients periodically compare their local copy of the state parameters with the copy on the server. If some differences are found that require updating the local display, that client will issue the update request. Again, depending on the division of subtasks, some requests are fulfilled by the client only, while the others require that the server sends updated image/information.

[0024] Referring now to Fig. 5, the steps involved in state parameter updating will be described. State parameter updating is controlled by the client-side conferencing software running on receiving stations 300a-e. At step 501, a check is made with a system clock, or another timing source, to determine whether the amount of time that has elapsed since the last state parameter update, Δt, is equal to a predetermined timing parameter, P_t, which determines the frequency with which the state parameters are updated. If $\Delta t \geq P_t$, then step 502 is performed. If $\Delta t < P_t$, then control returns to the beginning of the routine. For example, P_t may be 0.25 to 0.5 seconds. At step 502, one of the receiving station 300 sends a request to the transmitting station for current

state parameters associated with the current conferencing session. At step 503, the receiving station 300 compares the state parameters which have been stored locally to the state parameters that are received from the transmitting station after the request made in step 502. If the client state parameters and the server state parameters are equal, then control returns to the beginning of the routine. If the two sets of parameters are not equal, this implies that additional subtasks have been specified by the conference driver, and the routine proceeds to step 504. At step 504, the client sends a request for new image data if the parameters that have changed indicate that new image data has been generated. On the other hand, if only state parameters relating to brightness or contrast level, for example, are changed, then no new image data need be requested, because this change can be processed on the data already stored at the client. At step 505, the client state parameters are set equal to the updated server state parameters. At step 506, Δt is set equal to zero.

[0025] What has just been described is an on-demand image transmission method. Unlike the existing conference systems, image transmission occurs only when needed, and therefore, the network utilization efficiency is greatly improved.

[0026] In an alternative embodiment, a "push" implementation is utilized. In the push implementation, state parameters are transmitted to the clients whenever they are changed. Also, new image data is transmitted if, as described above, the change in the state parameters required new server-side image processing.

[0027] In another alternative embodiment, all remote conference participants may have already had the copy of the same data set on each of their local disk. This may be the case for training or educational applications in which a standard set of data is utilized. In this case, no image data transmission is required over the network. Based on the state parameters maintained on the server, the conferencing software running on each participant's computer will generate the new image using the local copy of the data and local computing resources and will synchronize the image display. This embodiment is useful

when the conference participants only have relatively-narrow bandwidth connection, such as a phone line, which is adequate to communicate the state parameters interactively, but not adequate for transmitting big data files, such as images, at rate allowing real time interaction. Updated state parameters in this embodiment may be transmitted to the clients either in a push implementation or a pull implementation.

[0028] As part of the preferred embodiment, any participant in a conference may request to become the driver. Upon approval from the current driver, the driver privilege may be switched to the requesting participant. The new driver will then have the full control of the image/data set under study, *i.e.*, the ability to define new state parameters. The new driver, *e.g.*, a surgeon, may fine tune the 3D model or other parameters to achieve the best view for his intended application.

[0029] The present invention may also be applied to multi-center trial studies, when constant communication of comprehensive information including images and data are needed between multiple participants. One example is a Magnetic Resonance Angiography (MRA) multi-center trial. In an MRA study, a 3D volumetric data set, comprised of a stack of 2D images, is acquired. This 3D volumetric data set is processed to extract the vascular structure, while minimizing the interference of other unwanted structures. In order to select the highest quality protocols and design the most effective trial, the participants need to view not only the acquisition protocol and the original 2D images, but also the processed 3D MRA images in detail.

[0030] The existing multi-center trial procedures face several challenges. First, in order to reach consensus on trial protocols, principle investigators from participating institutions may need to travel to different locations multiple times, making this process time consuming and expensive. Second, the current procedure of site selection, training, and trial monitoring require frequent travel by the trial monitors to various participating sites, making this process heavily dependent on the trial monitors' travel schedule and availability. Third, the current process calls for transferring of all the patient

data/images to a centralized position, demanding significant amount of pre-work to modify studies headers and preserve patient privacy.

[0031] The present invention provides an optimized method for multi-center trial management using the teleradiology conferencing technology. This method is designed to optimize the workflow and management of various tasks, such as protocol selection, training/education, trial monitoring, and data management for expert reading.

[0032] The steps for future multi-center trial management using the present invention include:

1) Using the teleradiology conferencing techniques described herein to choose a trial protocol;

2) Subsequently using the training embodiment of the teleradiology conferencing techniques described herein to conduct interactive conferences hosted by the sites experienced in the selected protocols to provide training/education to other participating sites using the mechanism described in the above section;

3) Using the teleradiology conferencing techniques described herein to conduct interactive conferences between the trial monitor and individual participating sites to review images, in order to assure quality and compliance during trial process;

4) Using the teleradiology techniques described in our application, U.S. Serial No. 09/434,088, and the present invention to allow an expert reader to remotely review, and interactively process if needed, 2D/3D image sets store at centralized or disparate locations, without physically transmitting the entire image sets; and

5) Reporting Expert reader will report blind read results using the integrated reporting tools provided by a system based on the present invention.

[0033] While the present invention has been described in its preferred embodiments, it is understood that the words which have been used are words of description, rather than limitation, and that changes may be made without

departing from the true scope and spirit of the invention in its broader aspects. Thus, the scope of the present invention is defined by the claims that follow.